DEUTERIUM ARRAY MEMO #063

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To: Deuterium Array Group

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Subject: Effects of a non-uniform interstellar medium

The expected D1 profiles derived in memos 52 and 53 assumed a uniform interstellar medium. There is evidence that the interstellar medium is "clumpy" and one theory has the medium divided into cold regions (Cold Neutral Medium or CNM) and warm regions (Warm Neutral Medium or WNM). These regions may have very different spin temperatures and density that are in pressure balance with each other, the CNM being around 60K and the WNM being around 5000 K. In the case of a line of sight which goes through a large number of CNM and WNM regions the equation of radiative transfer is given in the limit by

$$T_B = T_c \left(1 - e^{-\tau}\right) + T_{eff}\ e^{-\tau}$$

where T_B = brightness temperature
T_c = background temperature
T_{eff} = effective spin temperature
τ = opacity

$$T_{eff} = \left(T_{CNM} + a\ T_{WNM}\right)/\left(1 + a\right)$$

where a is the relative contribution of the WNM to the CNM opacity. For example if the WNM and WCM columns have equal total numbers of atoms with the same velocity dispersion along the line of sight then

$$a = T_{WNM}/T_{CNM}$$

and $Teff = 2\,T_{CNM}T_{WNM}/\left(T_{CNM} + T_{WNM}\right)$ = 119 K for T_{CNM} = 60 K and T_{WNM} = 5000 K

However the WNM and CNM regions will have different line widths even if the turbulence is the same because the kinetic contribution is

$$\left(\frac{KT}{m}\right)^{1/2} = \left(\frac{T}{121}\right)^{1/2} km/s \text{ for hydrodgen}$$

The effect is to make the factor opacity ratio a function of velocity so that T_{eff} will be higher on the wings of the line. However, the effect on the line profile is very small. The profiles for the case of a uniform 120 K vs 60K/5000K mix is shown in figure 1.

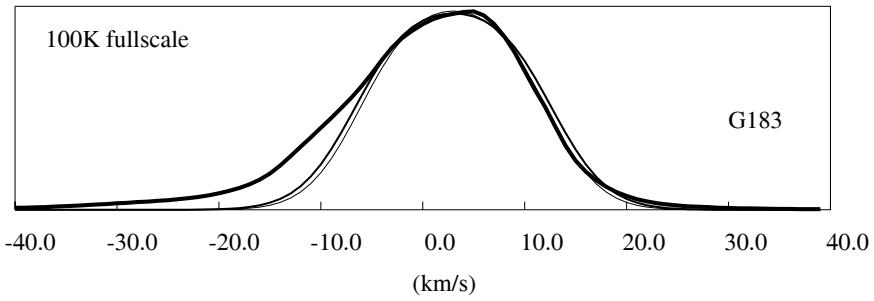

Figure 1. Thick curve is H1 line profile from Hartmann and Burton convolved with 5 degree beam. The thin curves are calculated from Gaussian opacity centered at 3 km/s with 14 km/s turbulence added to the kinetic width. The thicker of these is the CNM/WNM mixture.

Reference:

"Neutral Hydrogen and the diffuse interstellar medium," Kulkarni and Heiles in *Galactic and Extragalactic radio astronomy*, Verschur and Kellermann editors, 2nd edition Springer-Verlag 1988.